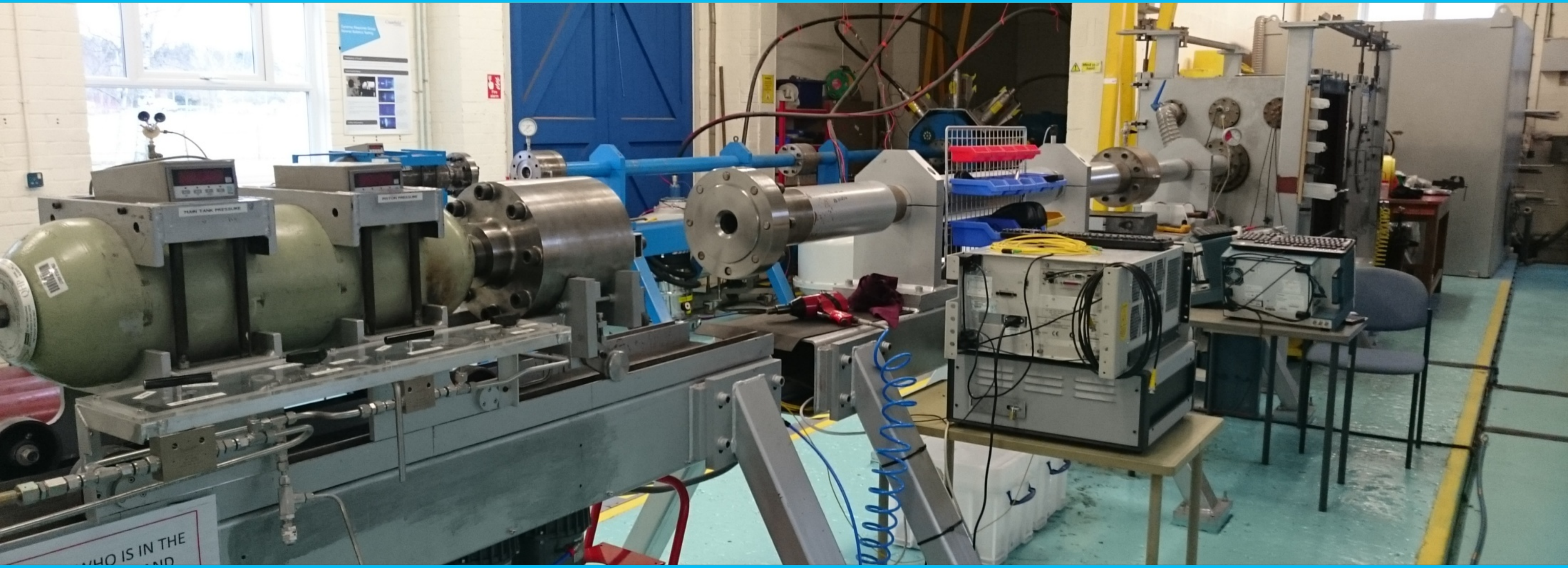
On the shock response of UHMWPE (Dyneema®)



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Purpose of experiments

- To investigate the shock response of a ultra-high-molecular-weight polyethylene, known as Dyneema® with respect to fibre orientation
- Properties investigated were shock and release velocities, orientations as well as comparisons to other Dyneema® composites
- Useful for understanding post shock elastic and plastic behaviour as well as formation / removal of hot spot zones within explosive materials

Previous work

- Chapman *et al.* investigated the 0° orientation of a non-specified variety of Dyneema®. Found a non-linear Hugoniot in U_S-u_p plane. No deviation on P-u_p from Hugoniot.

- Hazell *et al.* non-linear Hugoniot in the U_S-u_p plane agreeing with the Hugoniot found by Chapman *et al.*, no pressure values given. An elastic precursor was seen which disappeared when fibre melting occurred.

Previous work (continued)

- Lässig *et al.* expanded upon the low (less than 0.17 mm/μs) and high (1 to 2 mm/μs) particle velocities, albeit, a different Dyneema® variety. The high u_p values obtained using shock reverberation technique. Again a non-linear Hugoniot was found.

- The previous dataset by Hazell *et al.* will be expanded on with regards to strength measurements as well as release velocities, with new data also added.

Material used

- Dyneema® HB50 from DSM
- Consists of 16 µm unidirectional polyethylene fibres (in a 0°/90° configuration) in a rubber matrix
- Fibre volume fraction is 82%
- The Dyneema® HB50 fibres have elastic sound speed of 11 mm/µs

Material properties

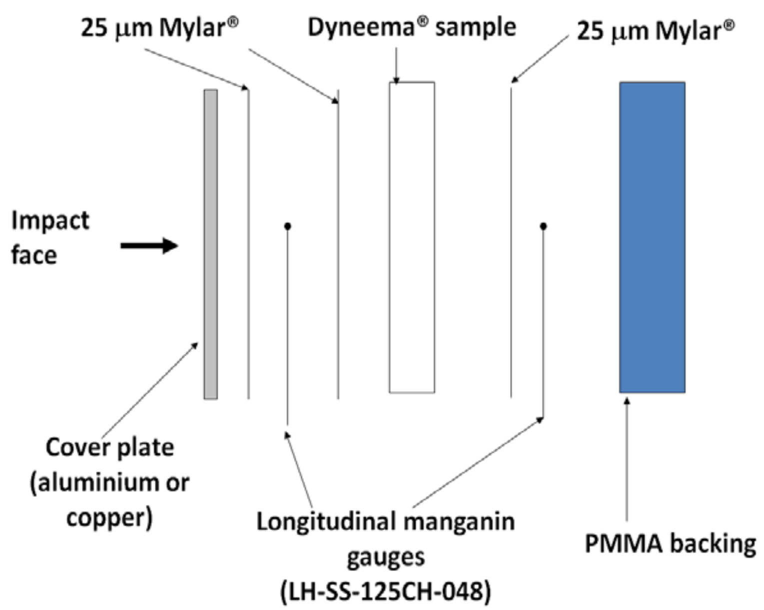
- Dyneema® HB50 investigated with fibres orientated at both 0° and 90° with respect to shock front
- Density is 0.95 g/cc
- Elastic properties of both orientations and polyethylene are

Material / Cloth Angle Degrees	ρ_0 g/cc	c_L mm/µs	c_S mm/µs	c_B mm/µs	v
Dyneema® 0°	0.95±0.03	2.10±0.10	0.97±0.10	1.78±0.14	0.36
Dyneema® 90°	0.95	8.00±0.30	2.7±0.10	7.34±0.32	0.43±0.01
Polyethylene	0.95±0.02	2.36±0.03	1.01±0.04	2.05±0.05	0.388

Experimental procedure

- Plate impact experiments – single stage light gas gun accelerating flat and parallel flyers to 1032 m/s

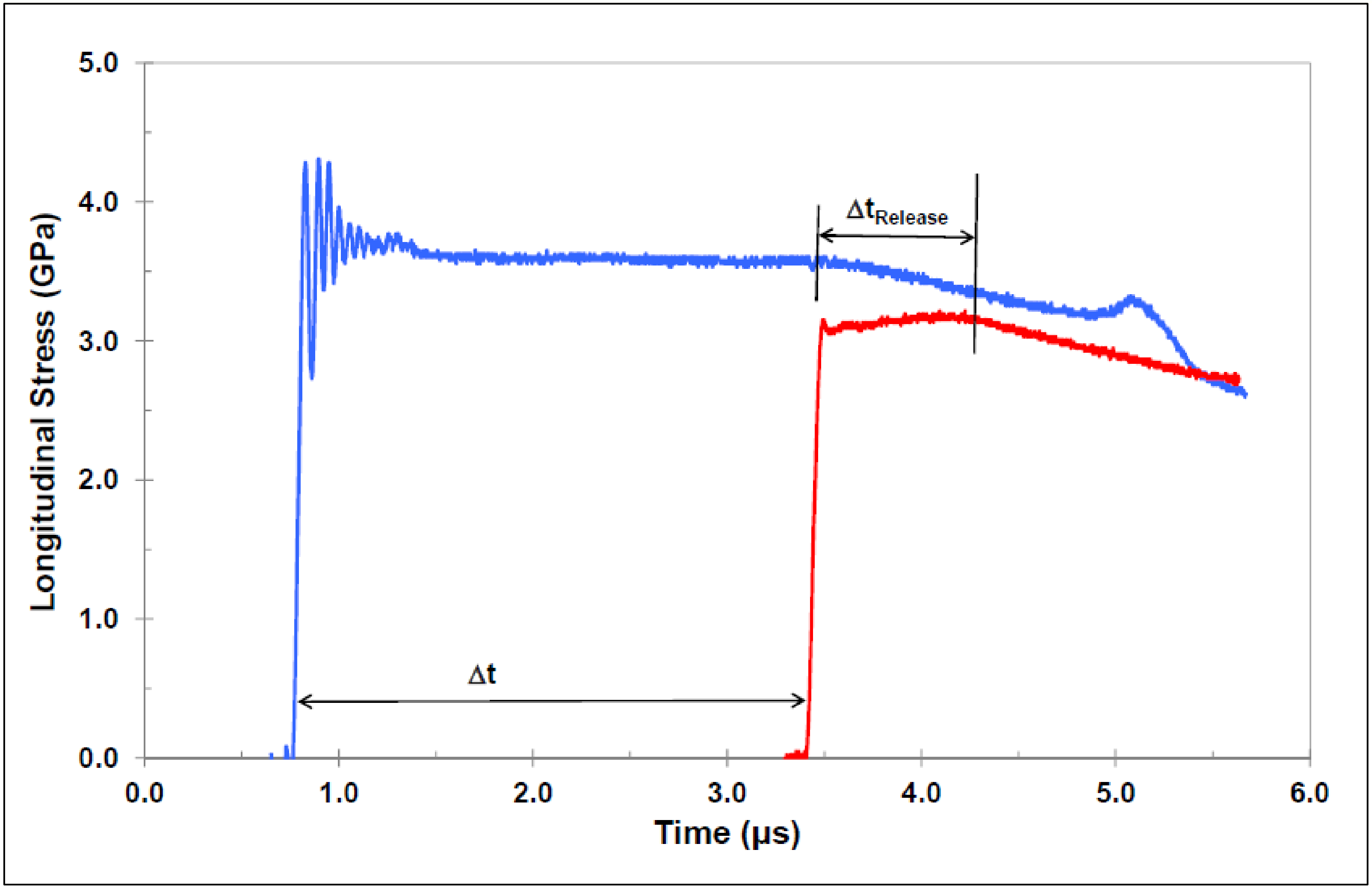
- Diagnostic employed manganin pressure gauges from Vishay micro-measurements (LM-SS-125CH-048), calibrated according to Rosenberg *et al.*



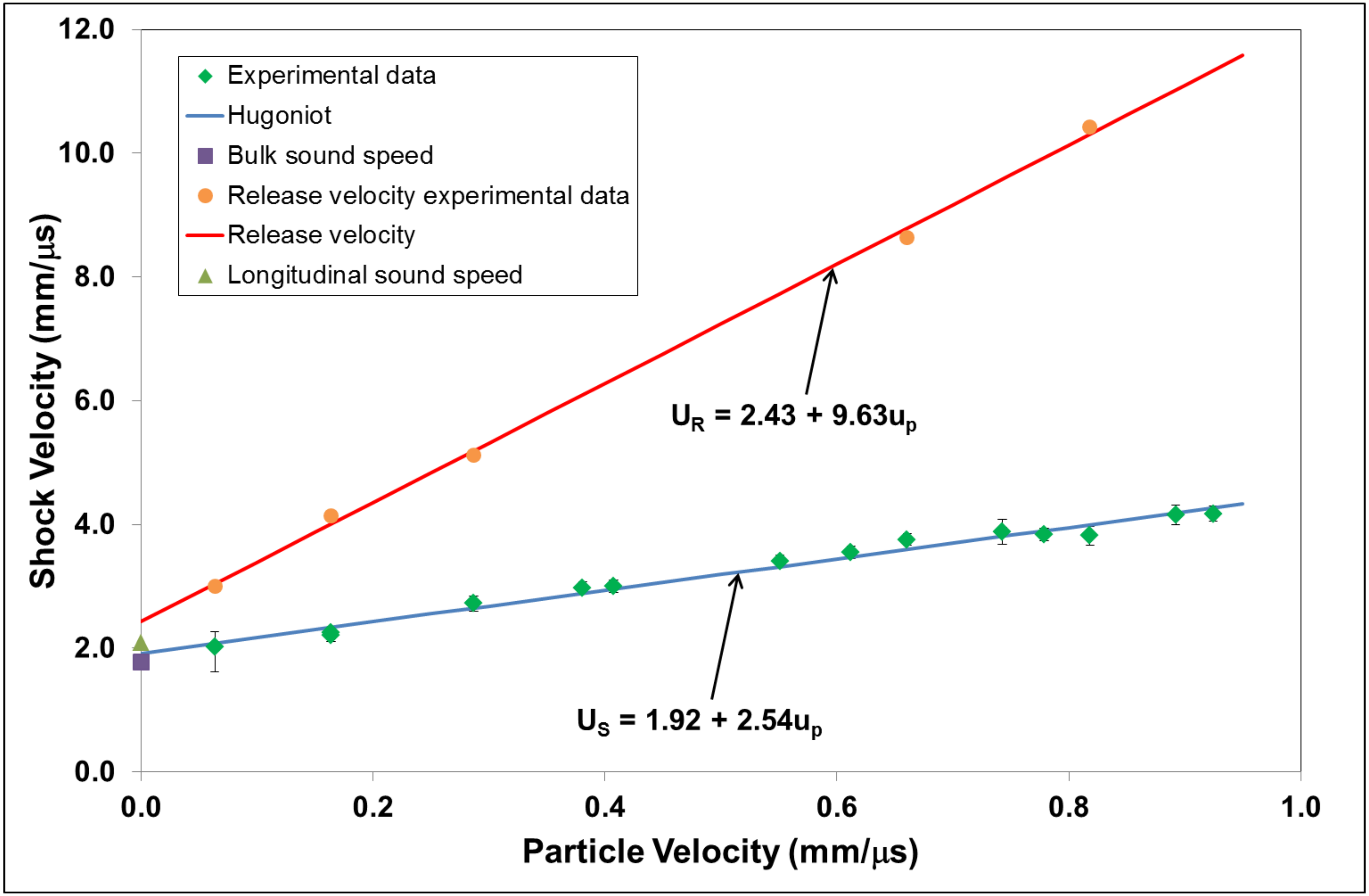
Equations employed

- Hugoniot tends to be linear and follow the form
  - $U_S = c_0 + Su_p$
- Non-linear ones can be used, and are seen primarily with polymers
  - $U_S = c_0 + S_1 u_p + S_2 u_p^2$
- To calculate U_S
  - $U_S = \Delta x_0 / \Delta t$
- To calculate the release velocity U_R
  - $U_R = (1 - u_p/U_S)(x_0/\Delta t_R)$

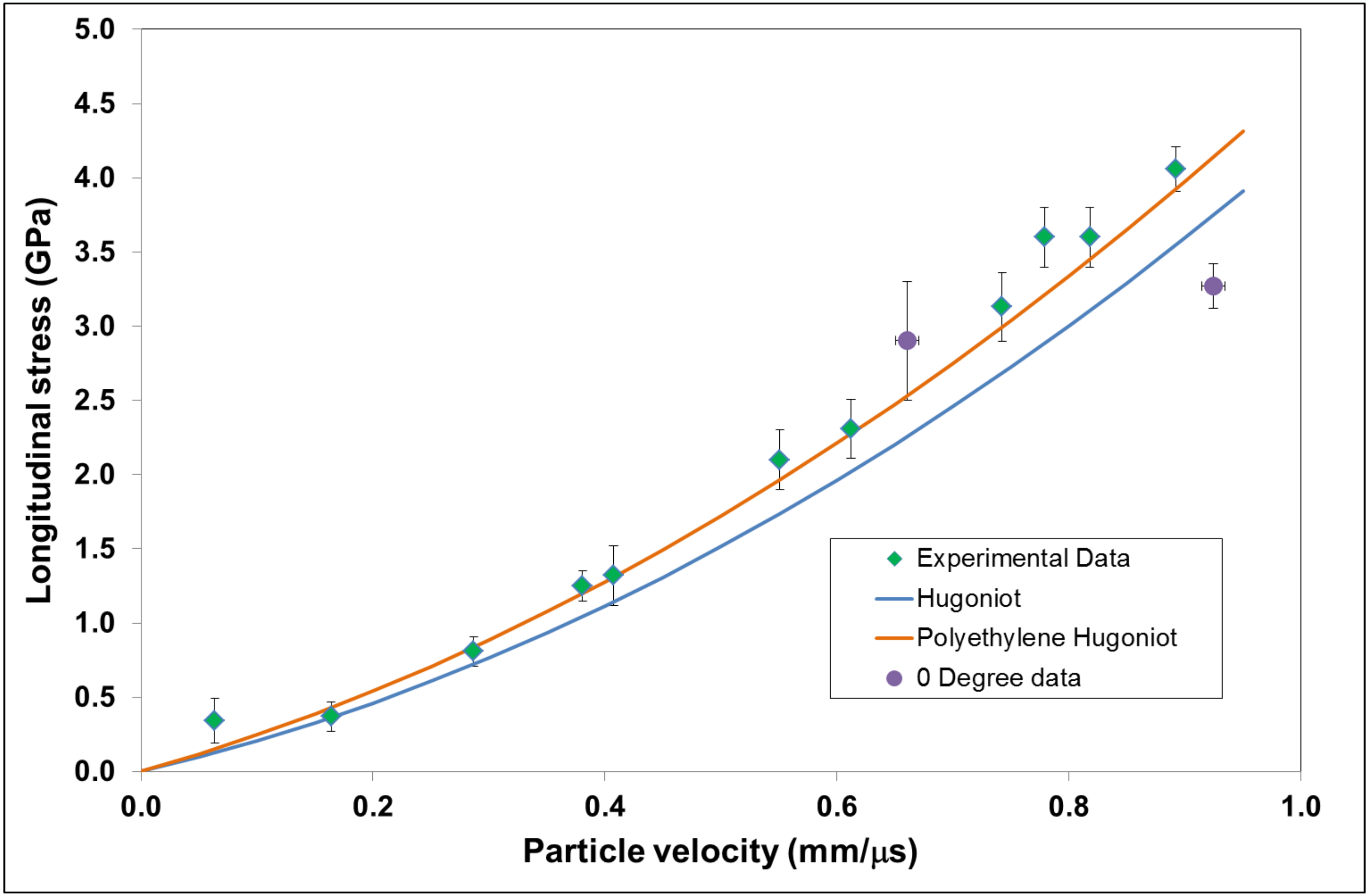
Experimental trace



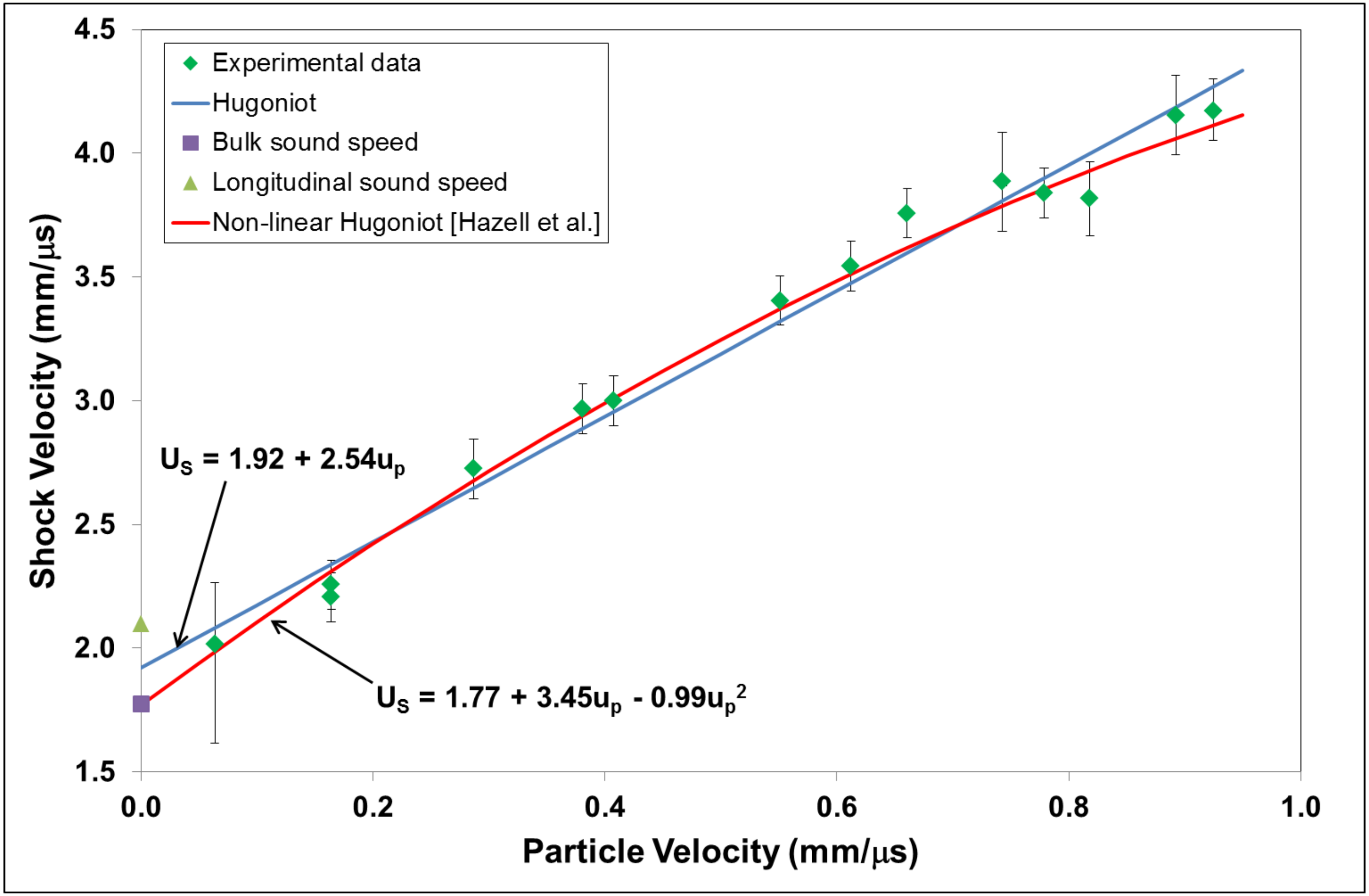
Hugoniot in the shock – particle velocity plane



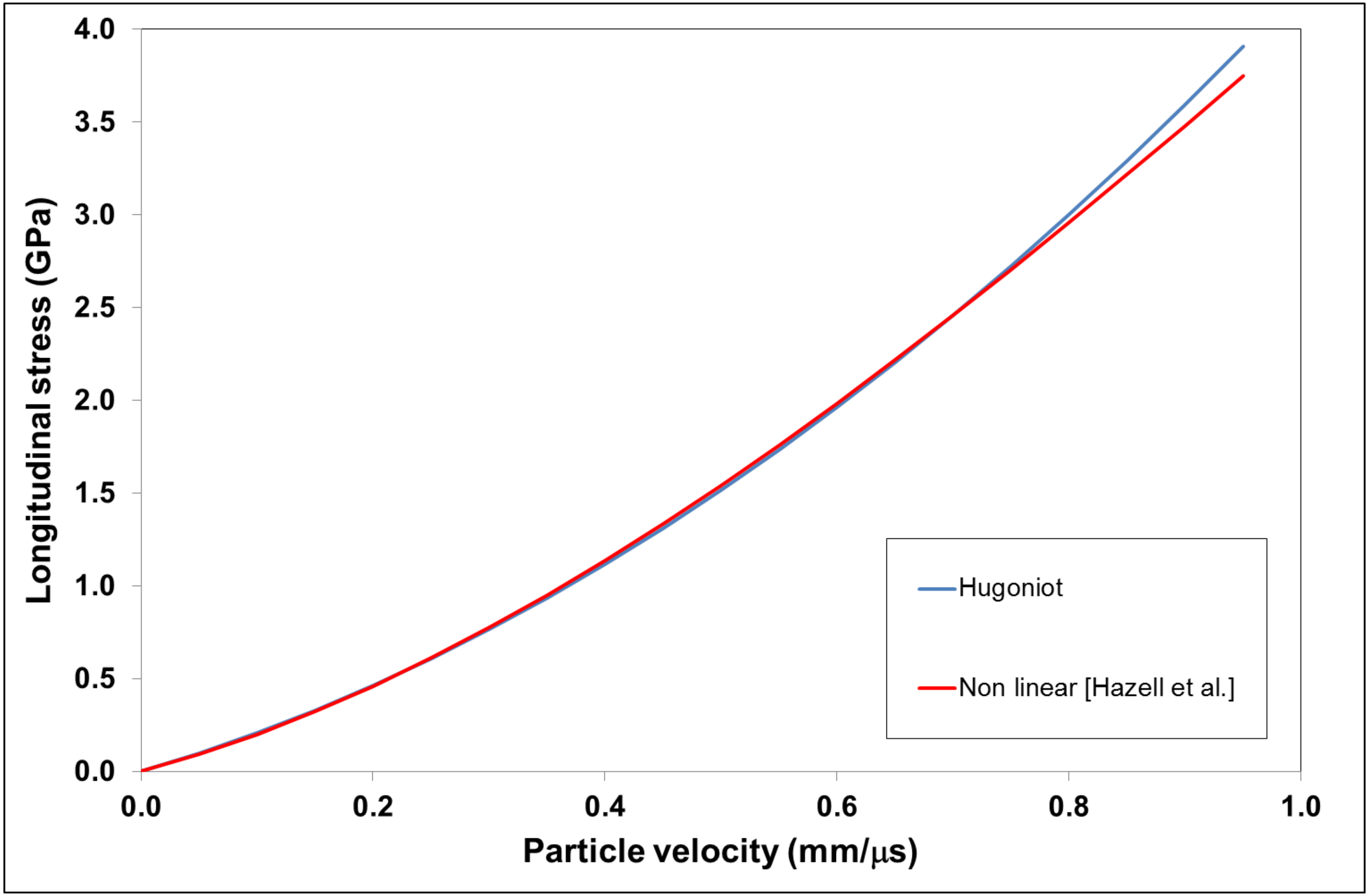
Hugoniot in the stress – particle velocity plane



Linear versus non-linear U_S-u_p Hugoniot



Linear versus non-linear P-u_p Hugoniot



Summary and conclusions

- A linear Hugoniot over the investigated range can be used. The equation is

  $U_S = 1.92 + 2.54u_p$

- Release velocity had a linear equation of

  $U_{release} = 2.43 + 9.63u_p$

- In the P-u_p plane, pressure was the same as for polyethylene, not the Hugoniot for Dyneema® as observed by Chapman *et al.*, this however, was for a different composition

Future work

- More data at high end to observe fibre melting, using shock recovery technique for post-impact analysis

- Also with regards to the high end data, more experiments on the shock release behaviour to see if there is an alteration of the release velocity

Acknowledgements

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Questions?

References

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